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(54) Method and apparatus for identifying a location of a lost token signal in a data communication network.

(57) Apparatus and method for identifying the location of a lost token signal customarily transmitted on transmission paths (15, 16) interconnecting nodes (2-7) of a network (1) to sequentially enable the nodes to write data messages onto the network. The arrival of the token signal at each node is recorded in binary counter states of a token track counter (10607) corresponding with the node. The recorded binary counter states are compared upon the failure of the token signal to arrive at a node to detect mismatches occurring between adjacent nodes binary counter states identifying the network location of the lost token signal.

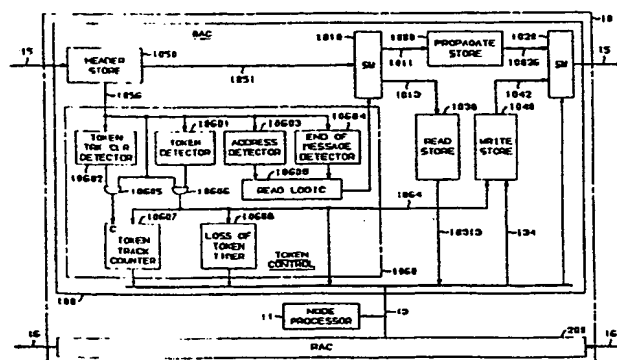


FIG. 2

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## METHOD AND APPARATUS FOR IDENTIFYING A LOCATION OF A LOST TOKEN SIGNAL IN A DATA COMMUNICATION NETWORK

### Technical Field

The invention relates to data communication networks using a token signal to enable access thereto.

### Background and Problem

Data Systems use data communication networks to exchange data. Typically, a data communication network, hereinafter called network, has transmission paths interconnecting nodes each coupled to data systems and each arranged to write data generated by an originating data system onto the network transmission paths and to read data received on the network transmission paths and addressed to a destination data system off the network.

These networks oftentimes use a token signal which is continuously transmitted on the network transmission path to sequentially arrive at each node. In order to control the traffic flow on the network and to prevent one node from continuously transmitting data on the network thereby denying other nodes access, each node is inhibited from writing data onto the network until the node receives the token signal. When a node receives the token signal, the node is thereby enabled to write data onto the network exclusive of all other nodes. A problem arises in these networks in that the token signal is sometimes inadvertently lost. This may occur because of equipment failures either in the nodes or transmission paths, or both, and results in an operational failure in that data systems are unable to write data onto the network thereby rendering the network inoperative until such time as the network location wherein the token signal was lost is identified.

### Solution

The foregoing problem is solved and a network having nodes interconnected by transmission paths wherein a token signal transmitted on the transmission paths sequentially enables each node to write data onto the network is substantially enhanced by a network method and apparatus having counter states for recording an arrival of the token signal at each node and for comparing the counter states of adjacent nodes to detect mismatches identifying a network location of a loss of the token signal.

The illustrative network comprises apparatus

having a pair of binary counter states corresponding with each node for detecting an arrival of the token signal at the node and for recording the node of the token signal arrival in ones of the binary counter states. A predetermined interval of time is initiated upon the detection of the token signal arrival at each node, and upon an expiration of the time interval indicating a loss of the token signal in the network, the apparatus registers a current status of the binary counter states. The registered status of the binary counter states are compared to identify a network location wherein the token signal was lost from mismatches occurring in ones of adjacent node registered binary counter states. The network is reconfigured to isolate the identified network location of the lost token signal and another token signal is written onto one of transmission paths of the reconfigured network to restore operation of the network.

### Brief Description of the Drawing

Fig. 1 is a block diagram of a network embodying the principals of the invention;

Fig. 2 illustrates the functional apparatus relationship of node of the network set forth in Fig. 1;

Fig. 3 illustrates the functional apparatus relationship of a node and ring control processor set forth in Fig. 1;

Fig. 4 illustrates the inter-relationship of the node functional apparatus for a counter-rotating ring network of the type set forth in Fig. 1;

Fig. 5 sets forth an illustrative section of a processor memory provided for use in the network nodes and ring control processor set forth in Fig. 1; and

Figs. 6 through 10 illustrates a flow chart of the operation of the network set forth in Fig. 1 in accordance with the principles of the invention.

### Detailed Description

Network 1, Fig. 1, may be a type of network as disclosed by M. L. Blood et al. in U.S. Patent No. 4,554,659 issued on November 19, 1985, and by D. M. Rouse et al. in U.S. Patent No. 4,683,563 issued on July 28, 1987. Network 1 has a number of nodes 2 through 7 interconnected by transmission paths 15 and 16 to form an illustrative network wherein nodes 3,4,6 and 7 couple data systems to network 1 in order that data may be selectively exchanged between data systems. A node 3,4,6

and 7 may be connected by a data bus 13 with a node processor 11 and line interface unit 12 for terminating data links 14 coupling data systems with network 1. Node 2 and 5 may interconnect ring control 18 with network 1 by data bus 17 to a node interface unit 12.

In operation, a data system transmits data over data link 14, through line interface unit 12 and data bus 13 to a node processor 11. Node processor 11 formats the received data into a data message similar to the message format disclosed by the aforementioned U.S. Patents 4,554,659 and 4,683,563. The data message is subsequently transmitted over data bus 13 to an originating node and written onto a directional transmission path 15, 16 and transmitted to a destination node. The destination node reads the data message off a transmission path 15, 16 onto data bus 13 into node processor 11. Data of the received data message is transmitted via data bus 13, through line interface unit 12 and over data link 14, to a receiving data system. Network 1 may transmit the data message over transmission paths 15, 16 through one node, data buses 17, ring control 18 and another node to a different network sector wherein is located a destination node.

The present embodiment of the invention assumes that each node is identical in performance and structure to other nodes and only a node 10, Fig. 2, need be described for an understanding of the invention. It is further assumed that each node, Fig. 1, may have a pair of ring access controls 100, 200, one of which corresponds with transmission path 15 and the other with transmission path 16. Each node ring access control 100, 200 is identical in performance and structure to the other and each, Fig. 3, is coupled by data bus 13 to node processor 11. An incoming transmission path, Fig. 1, such as transmission path 15, is connected to header store 1050 which is connected to switch 1010 and token control 1060. One output of switch 1010 is coupled to read store 1030 which is coupled via data bus 13 to node processor 11. Switch 1010 is also connected to propagate store 1000 which is connected by switch 1020 to outgoing transmission path 15. Each node ring access control 100, 200 has a write store 1040, 2040 connected by data bus 13 with node processor 11 and to switch 1020 in order that data messages may be selectively written onto outgoing transmission path 15.

Each node ring access control 100, 200 has a token control 1060, Fig. 2, provided with an address detector 10603 and an end-of-message detector 10604 coupled with read logic 10609 arranged to control operation of switch 1010. Token control 1060 also has a token detector 10601 and token track clear detector 10602 coupled respectively to inputs of logic gates 10606, 10605. Logic

gate 10606 is coupled via lead 1064 to write store 1040, data bus 13, loss-of-token timer 10608 and along with logic gate 10605 to token track counter 10607. The outputs of token track counter 10607 and loss-of-token timer 10608 are coupled with node processor 11 and write store 1040 via data bus 13.

A node receiving a data message on transmission path 15 stores the address portion in header store 1050. Address detector 10603 examines the address stored in header store 1050, and if the data message is addressed to this node, it enables read logic 10609 to control switch 1010 to connect lead 1051 with read store 1030 via lead 1013. The incoming data message is transmitted from header store 1050 through switch 1010 to read store 1030. When the end of the incoming data message is detected by end-of-message 10604, read logic 10609 is controlled to operate switch 1010 to switch transmission path 1051 to transmission path 1011. Subsequently, the stored data message is transmitted from read store 1030 over data buses 10313 and 13 to node processor 11. Node processor 11 processes the received data for use in controlling the operation of node 10 or formulates data that is transmitted via data bus 13 and line interface unit 12, Fig. 1, over a data link 14 to a destination data system. If address detector 10603, fig. 2, determines from the address portion stored in header store 1050 that the incoming data message is addressed to another node, read logic 10609 remains in a normal state whereby switch 1010 continues to connect transmission path 1051 with transmission path 1011. The incoming data message is transmitted from header store 1050 through switch 1010 to propagate store 1000. Subsequently, the data message is transmitted from propagate store 1000 over transmission path 10026 and through switch 1020 onto outgoing transmission path 15.

During an initialization sequence prior to writing a token signal onto the transmission paths 15, 16, ring control 18, Fig. 1, transmits a initialization data via data bus 17, line interface unit 12 and data bus 13 to a node processor 11. Node processor 11 formats an initialization data message and transmits the formatted initialization data message over data bus 13 to write store 1040. In addition, node processor 11 activates switch 1020 to connect write store 1040 with outgoing transmission path 15 so that write store 1040 may force write the initialization data message onto transmission path 15. The data initialization message is subsequently transmitted on transmission path 15 to sequentially reach each node of network 1. Header store 1050, Fig. 2, of each node detects the incoming initialization data message and enables an input of logic gate 10605 so that token track clear detector 10602

may clear token track counter 10607. Token track counter 10607 is a counting device capable of assuming counter states in response to an input received from logic gate 10606. It may be a memory device having pairs or a pair of binary counter states wherein is recorded a count of the output signals generated by logic gate 10606.

Upon initialization of network 1, ring control 18, if provided, or a node having a token control, writes a token signal onto a transmission path 15, 16. Ring control 18, or a token control, subsequently records the identify of the node that wrote the token signal onto network 1. The token signal is continuously transmitted on transmission paths 15 and 16 to sequentially enable each node having data to write a data message onto network 1 for transmission to a destination node. The token signal received on incoming transmission path is stored in header store 1050. Token detector 10601 detects the presence of the received token signal in header store 1050 and enables an input of logic gate 10606. Receipt of the token signal in header store 1050 enables the other input of logic gate 10606 to advance the count of token track counter 10607. Operation of logic 10606 also initializes loss of token timer 10608 to start the beginning of a predetermined interval of time the length of which is greater than the period of time that it takes the token signal to travel around transmission paths 15, 16 of network 1 when network 1 is handling a maximum amount of data message traffic.

Logic gate 10606 also enables node token control 1060 to place signals on lead 1064 and data bus 13 to inform write store 1040 and node processor 11 of the token signal arrival. If node 10 has a data message to write onto network 1, node processor 11 enables switch 1020 to connect write store 1040 to outgoing transmission path 15 so that write store 1040 may write the stored data message onto network 1. After write store 1040 has finished writing the data message onto outgoing transmission path 15, node processor 11 operates switch 1020 to disconnect write store 1040 from and reconnect propagate store 1000 to outgoing transmission path 15. The stored token signal previously transmitted from header store 1050 through switch 1010 to propagate store 1000 is then transmitted through switch 1020 onto outgoing transmission path 15. If there are no data messages stored at node 10, then the token signal is transmitted from header store 1050 through switch 1010, propagate store 1000 and switch 1020 onto outgoing transmission path 15.

The token signal, Fig. 1, continuously transmitted around network 1, sequentially enables each node 2 through 7 having data to write data messages onto network 1. Token detector 10601, Fig. 2, enables token track counter 10607 of each node

to record the token signal arrival at the node and initializes loss of token timer 10608 to start the predetermined interval of time. Since node 2, Fig. 1, initially wrote the token signal onto network 1, token track counter 10607, Fig. 2 of node 2, records a zero in one of the binary counter states thereof. As the token signal continues its journey around transmission path 15, token track counters 10607 of nodes 3 through 7 are successively set to record a one in one of the binary counter states thereof. When the token signal arrives back at node 2, token track counter 10608 of node 2 is advanced to record a one. As the token signal continues around network 1 on transmission path 15, token track counters 10607 of the network nodes 3 through 7 are advanced from one to zero and each node loss of token timer 10608 is initialized to start the beginning of the predetermined interval of time.

If the token signal is lost in network 1, Fig. 1, for example between nodes 3 and 4 on transmission path 15, node 4 loss of token timer 10608 times out at the expiration of the predetermined interval of time and notifies node processor 11 over data bus 13 that the token signal failed to reach node 4. Node processor 11, Fig. 2, registers the current status of the binary counter states by reading the contents of node 4 token track counter 10607 over the data bus 13 into memory. Assuming that token track counter 10607 of network nodes 2 and 3 had been set to one and zero, respectively, node 4, having not received the lost token signal, would continue to store a one in token track counter 10607. Node 4 processor 11, receiving the expiration of the predetermined interval of time as an indication of the loss of the token signal and registering the current status of one recorded in token track counter 10607, formulates a token signal lost data message for transmission to ring control 18.

The token signal lost data message includes information that the predetermined time interval of node loss of timer 10608 expired and that one is the current status of the node token track counter 10607. Node processor 11 addresses the token signal lost data message to ring control 18 and then transmits the formatted data message over data bus 13 to write store 1040. Switch 1020 is operated by node processor 11 to connect write store 1040 with outgoing transmission path 15 so that the formatted token signal lost data message may be force read from node 4 write store 1040 onto network 1. Although the present embodiment of the invention assumes that the formatted token signal lost data message is force read onto outgoing transmission path 15, it is to be understood that node processor 11 could have, Fig. 4, force written the formatted data message onto outgoing transmission path 16 via write store 2040 and

switch 2020. The node 4 token signal lost data message appearing on outgoing transmission path 15, Fig. 1, is received by node 5 and read off network 1 into read store 1030 thereof and transmitted over data bus 13 to node processor 11. Node processor 11 then transmits the received token signal lost data message through line interface unit 12 and over data bus 17 to ring control 18.

Sequentially, loss of token timer 10608, for each node 5 through 7 and 2 expires upon failure to receive the receive the loss token signal and each node transmits a token signal lost data message containing the one recorded in the node token track counter 10607 over a transmission path and data bus 17 in the aforementioned manner to ring control 18. Node 3, having last received the token signal, transmits a token signal lost data message containing a zero recorded in node 3 token track counter 10607 to ring control 18 over transmission path 16 to node 2, line interface unit 12 and data bus 17.

Ring control 18, Fig. 3, comprises a processor that may be a computer such as an AT&T 3B15 or 3B20 simplex or duplex computer. Such computers need not be described in detail for an understanding of the invention and in general have a central processing unit 180, memory unit 181 and interface unit 182 each connected by address, data and control leads to a central bus 183. Node processors 11 are similar in construction to ring control 18 but may be microprocessors such as a Motorola 68000 series or later design of microprocessors each having central processing unit 110, memory unit 111 and interface unit 112 connected by address, data and control leads to a central bus 113.

Each incoming node token signal lost data message is received by interface unit 182 and processed by central processing unit 180 such that the status of the binary counter states of the node token track counter 10607 of each node, 2 through 7, is registered in ring control memory unit 181. Assuming that the token signal was lost between nodes 3 and 4, ring control memory unit 181 would register each node token track counter binary counter states as set forth in Fig. 5. For example, node 2 having originally written the lost token signal onto network 1 may have recorded binary counter states 01 as the status of node 2 token track counter 10607. Node 3 having last received the lost token signal would have recorded the node 3 token track counter 10607 binary counter states of 10. Remaining network nodes 4 through 7 each would have recorded node token track counter 10607 binary counter states of 01.

Ring control central processing unit 180, Fig. 3, compares the received and registered token track counter binary counter states of adjacent nodes to

detect mismatches wherein transitions occurred between ones of registered node binary counter states. Thus, node 2, Fig. 5, is compared with adjacent node 7 and 3 and the transition occurring between node 2 and node 3 is logged as a possible location of the lost token signal. Node 3 is compared with adjacent nodes 2 and 4 and the transitions occurring between nodes 2 and 3 and between nodes 3 and 4 are logged as possible locations within network 1 wherein the token signal was lost. Ring control central processing unit 180 identifies network node 2 as having written the lost token signal onto network 1 and thereby eliminates the identity of node 2 from the comparison consideration. With node 2 eliminated, the one remaining transition occurring between the registered status of token track counter 10607 binary counter states of nodes 3 and 4 identifies the network location wherein the token signal was lost.

Ring control 18, Fig. 1, having identified the network location of the lost token signal, formats a reconfiguration data message and transmits the formatted data message over data bus 17 through line interface unit 12 to node processor 11 of node 5. Node processor 11 controls node 5 to force write reconfiguration data messages addressed to network nodes 3 and 4 onto outgoing transmission paths 15 and 16. Upon receipt of the reconfiguration messages, nodes 3 and 4 function to couple incoming transmission paths 15 and 15, respectively, to outgoing transmission paths 16 and 15 thereby reconfiguring network 1 to isolate the identified fault section of network 1 between nodes 3 and 4 from the active section of network 1 now existing between nodes 4 and 3 through nodes 5, 6, 7 and 2.

Ring control 18 further transmits an initialization data message over data bus 17 to node 5 which is formatted and force read onto outgoing transmission paths 15 and 16. The formatted initialization data message sequentially enables each node, Fig. 2, of the active section of the network to force read data messages from network 1 and to clear token track counter 10607 via logic gate 10605, token track clear detector 10602 and header store 1050. Thus, ring control processor 18 clears the reconfigured network of all data messages and initialized each node token track counter 10607 located in the reconfigured network. Ring control 18 also enables node 5, Fig. 1, to write another token signal onto looped transmission paths 15, 16 and records the identity of token signal writing node 5 in memory unit 181, Fig. 3. The new token signal transmitted on transmission paths 15, 16, Fig. 1, of the active section of reconfigured network 1, sequentially enables each node to write data messages onto network 1. The isolated fault section of the reconfigured network may then be repaired and restored to

active service.

In one embodiment of the invention, nodes and ring control 18 function together to identify a network location wherein a token signal is lost. In another embodiment of the invention, ring control 18 is arranged so that memory unit 181, Fig. 3, is configured to have pairs of binary counter states with each pair of binary counter states corresponding with one of the nodes. A node processor 11 of a node, for example node 4, detecting the arrival of the token signal informs ring control 18 that the token signal has arrived at node 4. Ring control central processing unit 180, Fig. 3, which may be connected by data bus 183 to each node processor 11, records the arrival of the token signal in a pair of the binary counter states corresponding to node 4 and initiates the start of a predetermined interval of time.

As the token signal is transmitted around network 1, each pair of node binary counter states in ring control memory unit 181 records the node arrival of the token signal and central processing unit 180 initiates the start of a predetermined interval of time unique to the node. If the token signal is lost, for example between nodes 3 and 4, node 4 and succeeding network nodes 5, 6, 7, 2 and 3 fail to notify ring control 18. Each node predetermined interval of time expires thereby notifying central processing unit 180 that a network loss of the token signal has occurred. Central processing unit 180 responds thereto by comparing the memory unit 181 binary counter states corresponding with adjacent ones of the nodes in the manner herein earlier described to detect transitions identifying the network location wherein the token signal was lost. After the network location is identified ring control 18 reconfigures network 1 to isolate the identified network location of the lost token signal and clears the reconfigured network of all data messages. Central processing unit 180 then controls memory unit 181 to initialize all of the node pairs of binary counter states and enables one of the network nodes 2, 5 to write another token signal onto one of the transmission paths 15, 16 of the reconfigured network.

In yet another embodiment of the invention, each or selected ones of the nodes are designated token control and the associated node processor memory unit 111, Fig. 3, is configured to have pairs of binary counter states with each pair of binary counter states corresponding with a node. A node processor 11, Fig. 1, of a node detecting the arrival of the token signal informs node processor 11 having token control of the arrival of the token signal at the node. Central processing unit 110, Fig. 3, of token control node processor 11 which may be connected by data bus 113 to each node processor 11, records the token signal arrival in a pair

of binary counter states corresponding to the token signal receiving node and initiates the start of a predetermined interval of time.

As the token signal is transmitted around network 1, each pair of node binary counter states in designated token control node processor memory unit 111 records the arrival of the token signal at a node and central processing unit 110 initiates the start of a predetermined interval of time unique to the node. If the token signal is lost, succeeding nodes fail to notify the token control node processor 11. Each node predetermined interval of time expires thereby notifying central processing unit 110 that a network loss of the token signal has occurred. Central processing unit 110 responds by comparing the memory unit 111 registered binary counter states corresponding with adjacent ones of the nodes in the manner herein earlier described to detect mismatches and transitions identifying the network location wherein the token signal was lost. After the network location is identified, the token control node processor 11 reconfigures the network to isolate the identified network location and clears the reconfigured network of all data messages. Central processing unit 110 controls memory unit 111 to initialize all of the node pairs of binary counter states and force writes another token signal onto one of the transmission paths of the reconfigured network.

In the operation of network 1, Fig. 6, a token signal, step 300, continuously circulates on transmission paths 15, 16 to sequentially enable each node to write data messages onto network 1. The method of locating a lost token signal comprises, step 301, detecting the arrival of the token signal at each node, step 3010, and recording the node detection of the token signal arrival in one of the pair of binary counter states by incrementing the node token track counter 10607 and initiating a predetermined interval of time. If the node does not have a data message, step 302, the token signal continues circulating on network transmission paths 15, 16. When there is data message at the node, the node writes the data message onto an outgoing transmission path 15, 16, and at the end thereof transmits the received token signal on the outgoing transmission path to the next node. If a node, step 304, fails to receive a token signal, the node loss of token timer 10608 expires, step 3040, and notifies node processor 11, step 3041, that a loss of token signal has occurred in network 1. Node processor 11, step 3042, force writes a token signal loss data message identifying the node token track counter binary counter states and addressed to ring control 18 onto a network transmission path 15, 16.

If the node does not have token control, Fig. 7, step 3055, a sequence is started, step 3056, whereby node processor 11, step 30560, sets the

node to assume a force propagate state and initiates, step 30561, a predetermined time delay so that data messages may be cleared from network 1. At the end of the predetermined time delay, node processor 11 clears the node of the force propagate state, step 30562, and exits the node routine. As each node lost of token time 10608 expires, a token signal lost data message addressed to ring control 18 is written onto the appropriate transmission path. Ring control 18, Fig. 9, receives each node generated token signal lost data message, step 30590, and registers the current status of the node token track counter 10607 binary counter states set forth therein and enters a sequence, step 305, of comparing the registered binary counter states to detect mismatches and transitions identifying the network location wherein the token signal was lost.

Central processing unit 180 compares the registered binary counter states of each node with the registered binary counter states of adjacent nodes to identify mismatches and transitions. If there are none or only a single transition, step 30502, ring control 18 identifies the node used to write the lost token signal onto network 1 as the fault location. When there are multiple adjacent node transitions, step 30591, ring control 18, step 30593, determines node locations wherein the transitions and mismatches occurred and eliminates the identity, step 30594, of the node having first wrote the token signal onto network 1. Ring control 18, identifying the network location, step 30595, wherein the token signal was lost from the remaining transition occurring in compared ones of the registered node binary counter states passes the failure location to the recovery process, step 30596.

The recovery process, Fig. 10, checks to see if the failure location has been identified, step 3050, and if there is continuity of either network transmission path 15, 16, step 3051. Should it be determined that there is no continuity of either network transmission path 15, 16, ring control 18 invokes a hard fault search strategy, step 3052. Ring control 18 may generate an alarm signal to notify maintenance personnel that both network transmission paths 15, 16 are inoperative or may enter an interrupt mode to invoke emergency conditions for reestablishing continuity of at least one of the network transmission paths 15 or 16. When there is continuity of at least one of the network transmission paths 15 or 16, ring control 18 starts fault recovery, step 3060. A first step 3061 is to reconfigure network 1, Fig. 1, to isolate the identified network location of the lost token signal. Assuming that the token signal was lost between nodes 3 and 4, as determined from transitions occurring in the compared binary counter states of node 3 and 4 token track counters 10607, ring control 18 will

force read a data message onto network 1 instructing nodes 3 and 4 to loop connect transmission paths 15 and 16 together.

The reconfigured network is arranged such that data messages incoming on transmission path 15 to node 3 from node 2 and intended for other nodes are transmitted from node 3 on outgoing transmission path 16 to node 2. Similarly, data messages incoming on transmission path 16 from node 5 to node 4 and intended for other network nodes are transmitted from node 4 on outgoing transmission path 15 to node 5. Thus, a data message written onto reconfigured network 1 and incoming to node 4, Fig. 4, on incoming transmission path 16 is force read through switch 2010 and read store 2030 into node processor 11. When the network token signal is detected by node 4 token control 2060, node processor 11 writes the data message over data bus 13 into write store 1040 and through switch 1020 onto outgoing transmission path 15.

Once network 1 has been reconfigured to isolate the fault section assumed to be between nodes 3 and 4, ring control 18, step 3062, Fig. 10, clears the reconfigured network of all data messages by force reading the data messages into node processors 11. In addition, ring control 18 initializes the node binary counter states by writing an initialization data message, step 3063, onto a network transmission path. The initialization data message is transmitted on network transmission paths 15, 16 to sequentially reach each node 2 through 7 where it enables token track clear detector 10602, Fig. 2, to clear each node token track counter 10607 by initializing the binary counter states thereof. Ring control 18 then writes another or new token signal, step 3064, onto one of the transmission paths 15, 16 of the reconfigured network and records the identity of the node, for example node 2, having wrote the new token signal onto network 1 into memory unit 180. The new token signal is transmitted on the reconfigured network transmission paths 15, 16 to sequentially enable each node to write data messages onto reconfigured network 1. The isolated section may then be repaired and subsequently returned to service.

If a node has token control, Fig. 7, step 3055, the expiration of the predetermined time interval results in loss of token timer 10608, Fig. 2, notifying node processor 11 that the token signal has been lost. Node processor 11 interrogates token track counter 10607 and records the current status of the node binary counter states recorded therein, step 30570. In addition, node processor central processing unit 110, Fig. 3, starts a node processor guard timer, Fig. 8, step 30580. During the guard timer timing interval, node processor 11, step 30582, receives a token signal lost data message

from each node either over the network transmission paths 15, 16 or over a data bus interconnecting all node processors 11 and registers the received node binary counter states status in node processor memory unit 111, Fig. 3. When all of the node token signal lost data messages have been received, node processor central processing unit 110 cancels the guard timer, step 30583.

As set forth in Fig. 9, steps 30591 through 30596, a token control node identifies the network location wherein the token signal was lost from transitions and mismatches occurring between ones of adjacent node registered status of the node binary counter states. Upon identifying the network location of the lost token signal, node processor 11 initiates a recovery sequence, Fig. 10, steps 3050 through 3052 and 3060 through 3065, to reconfigure network 1 to isolate the fault section and restore the reconfigured network 1 to active service by writing another token signal onto the reconfigured network 1 to replace the one that was lost.

If node processor 11 having token control does not receive token signal lost data messages, interval guard timer expires, Fig. 8, step 30585. Should the fault location be identified, Fig. 10, step 3050, node processor 11 enters the fault recovery routine, step 306, to reconfigure network 1 to isolate the network section wherein the token signal was lost and to write another token signal onto reconfigured network 1. If the fault location has not been identified, step 3050, node processor 11 determines the continuity of either network transmission path 15, 16 and if there is continuity of at least one transmission path, step 3051, enters fault recovery routine, step 306. When continuity has been lost on both network transmission paths 15, 16 node processor invokes a hard fault search strategy, step 3052, to identify the fault location. After identifying the fault location, node processor 11 invokes fault recovery routine, step 306.

As earlier set forth, ring control 18 can identify the network location of a lost token signal. Each network node receiving the token signal generates a token signal data message that is addressed to ring control 18 and notifies ring control 18 via an interconnecting data bus of the arrival of the token signal at the network node. The method of operating ring control 18 comprises the step of detecting the arrival of the token signal at each node upon receipt of the node token signal data message and recording the node detection of the token signal arrival in ring control central processing unit 180 pairs of binary counter states corresponding to each network node. The ring control 18 method of operation further comprises the steps of initiating a predetermined interval of time upon recording each node token signal arrival and comparing upon an expiration of the predetermined interval of time

indicating a network loss of the token signal the network location of the lost token signal from mismatches occurring between adjacent node recorded status of binary counter states. After identifying the network location of the lost token signal, ring control 18 initiates a fault recovery sequence, step 306, Fig. 10.

## Claims

1. A network (1) having a network control processor (18) coupled with nodes (2-7) interconnected by transmission paths (15,16) wherein a token signal transmitted on the transmission paths sequentially enables a processor (11) of each node to write data onto the network with said network comprising apparatus enabled upon a network loss of the token for identifying a network location wherein the token signal was lost  
CHARACTERIZED IN THAT  
said network comprises  
apparatus (11,1060) having a plurality of counter states corresponding with each node for recording an arrival of the token signal at the nodes as a change of said node counter states, and  
means (11,18) associated with the recording apparatus for comparing ones of said recording apparatus counter states corresponding with adjacent nodes to detect mismatches occurring in said node counter states identifying a network location wherein the token signal was lost.

2. The token network of claim 1

### CHARACTERIZED IN THAT

said recording apparatus comprises  
detecting apparatus (10601, 10602) for detecting the arrival of the token signal at each node, and  
recording apparatus (10607) coupled with said detecting apparatus and having a pair of binary counter states for recording the node detection of the arrival of the token signal in said pair of binary counter states.

3. The token network of claim 2

### CHARACTERIZED IN THAT

said recording apparatus comprises  
timing apparatus (10608) enabled by said detecting apparatus upon detection of the token signal arrival at a node for initiating a start of a predetermined interval of time, and  
means (11) enabled by said timing apparatus upon an expiration of said predetermined interval of time as indicating a lost of the token signal for registering a current status of said node pair of binary counter states.

4. The token network of claim 3

### CHARACTERIZED IN THAT

said comparing means comprises  
apparatus (110, 180, 111, 181) for comparing said



registered status of each node pair of binary counter states with registered status of adjacent nodes pair of binary counter states, apparatus (110, 180, 111, 181) for eliminating an identity of a node having first wrote the lost token signal onto the network transmission paths, and apparatus (110, 180, 111, 181) for identifying the network location wherein the token signal was lost from mismatches occurring in compared ones of said registered status of node pair of binary counter states.

#### 5. The token network of claim 4

##### CHARACTERIZED IN THAT

said network comprises

apparatus (110, 112, 180, 181) for reconfiguring the network to isolate the identified network location of the lost token signal,

apparatus (110, 112, 180, 182) for clearing the reconfigured network of all data and for initializing each node recording apparatus pair of binary counter states,

apparatus (110, 112, 180, 182) for writing a new token signal onto one of the network transmission paths of the reconfigured network, and

apparatus (110, 112, 113, 180, 182, 183) for recording the identity of node having wrote said new token signal onto the network transmission path.

#### 6. The token network of claim 5

##### CHARACTERIZED IN THAT

each network node comprises

node detecting and recording apparatus (10601, 10602, 10607) for detecting the arrival of the token signal at the node and having a pair of said binary counter states for recording the node detection of the arrival of the token signal as a change of said binary counter states,

node timing apparatus (10608) enabled by detection of the token signal arrival at a node for initiating the start of said predetermined interval of time, node processor apparatus (11) enabled by said node timing apparatus upon an expiration of said predetermined interval of time as indicating a lost of the token signal for registering the current status of said node detecting and recording apparatus binary counter states therein, and

node transmitting apparatus (11, 1040) for transmitting the node binary counter states status registered in said node processor apparatus to the network control processor.

#### 7. The token network of claim 6

##### CHARACTERIZED IN THAT

said network control processor comprises

apparatus (182, 181) for receiving and registering the transmitted node binary counter states status of each network node, and

a processor (180) for comparing the registered status of each node binary counter states with the registered status of adjacent nodes binary counter

states and for eliminating the identity of the node having first wrote the lost token signal onto the network transmission paths and for identifying the network location wherein the token signal was lost from mismatches occurring in compared ones of said registered status of node binary counter states.

8. A method of identifying a location of a token signal lost in a network (1) having a network control processor (18) coupled with nodes (2-7) interconnected by transmission paths (15, 16) wherein a token signal transmitted on the transmission paths sequentially enables a processor (11) of each node to write data onto the network

##### CHARACTERIZED IN THAT

said method comprises the steps of recording (301, 304, 3011, 3012, 3058) an arrival of the token signal at each node in node binary counter states as a charge of the node binary counter states, and

comparing (305, 306) each of said recorded node binary counter states with binary counter states recorded in nodes adjacent to each node to detect mismatches of the recorded node binary counter states identifying the network location wherein the token signal was lost.

9. The method of identifying the network location of a lost token signal as set forth in claim 8

##### CHARACTERIZED IN THAT

said recording step comprises the steps of detecting (301) the arrival of the token signal at each node, recording (3011) the node detection of the arrival of the token signal in a pair of binary counter states,

initiating (3012) a predetermined interval of time in response to detecting said node token signal arrival, and

registering (304, 3058) a current status of said node binary counter states upon an expiration of said predetermined interval of time.

10. The method of identifying the network location of a lost token signal as set forth in claim 9

##### CHARACTERIZED IN THAT

said comparing step comprises the steps of

comparing (30590) said registered node binary counter states status of adjacent ones of the nodes, eliminating (30594) an identify of a network having wrote the lost token signal onto the network transmission paths, and

identifying (30595) the network location wherein the token signal was lost from mismatches occurring in ones of said compared registered node binary counter states status,

reconfiguring (3060, 3062) the network to isolate the identified network location of the lost token signal,

clearing (3061) the reconfigured network of all data and initializing said node pairs of binary counter

states,  
writing (3063, 3064) a new token signal onto one of  
the reconfigured network transmission paths, and  
recording (3065) and identity of a node enabled to  
write said new token signal onto the network trans-  
mission path.

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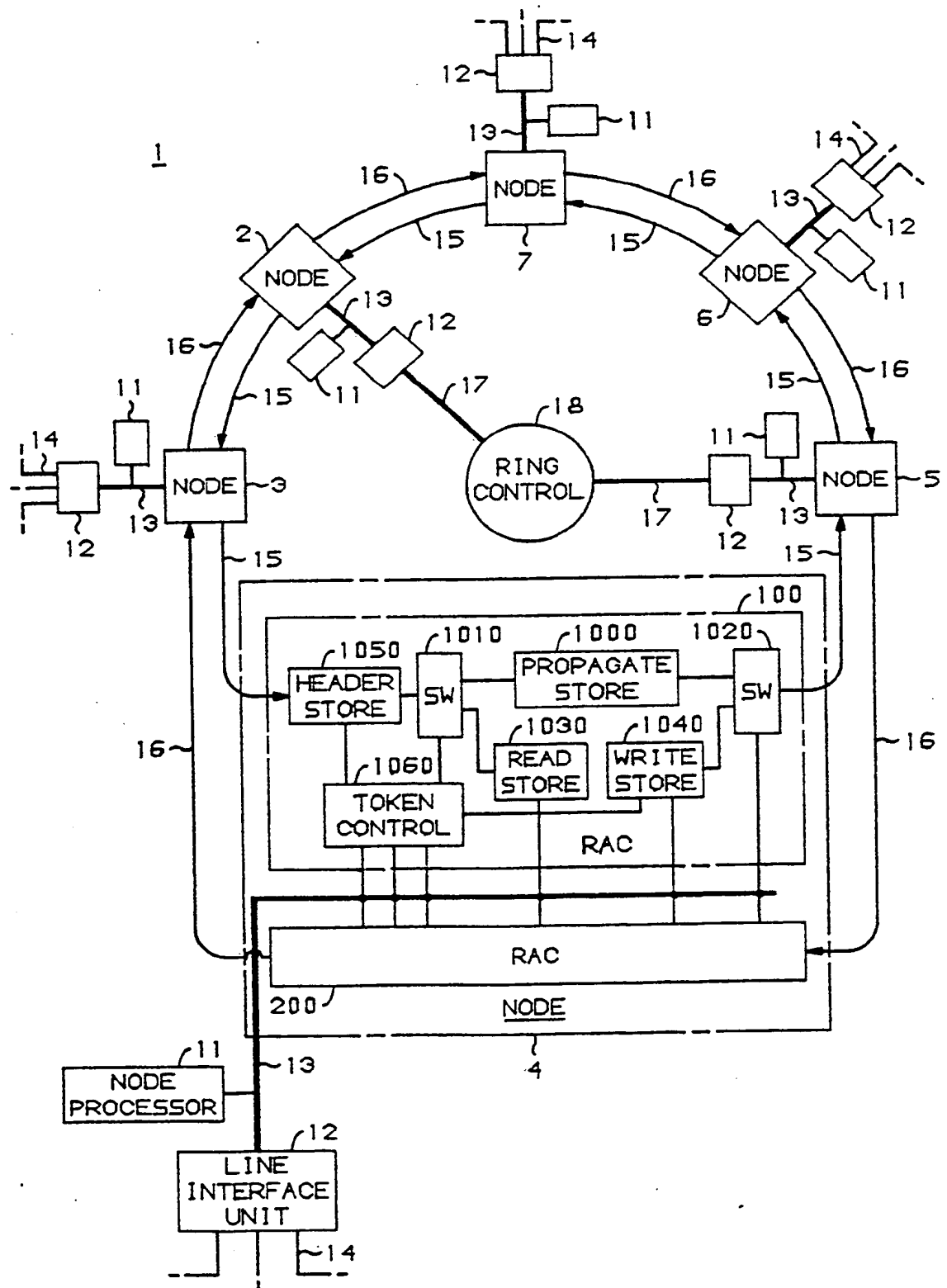


FIG. 1

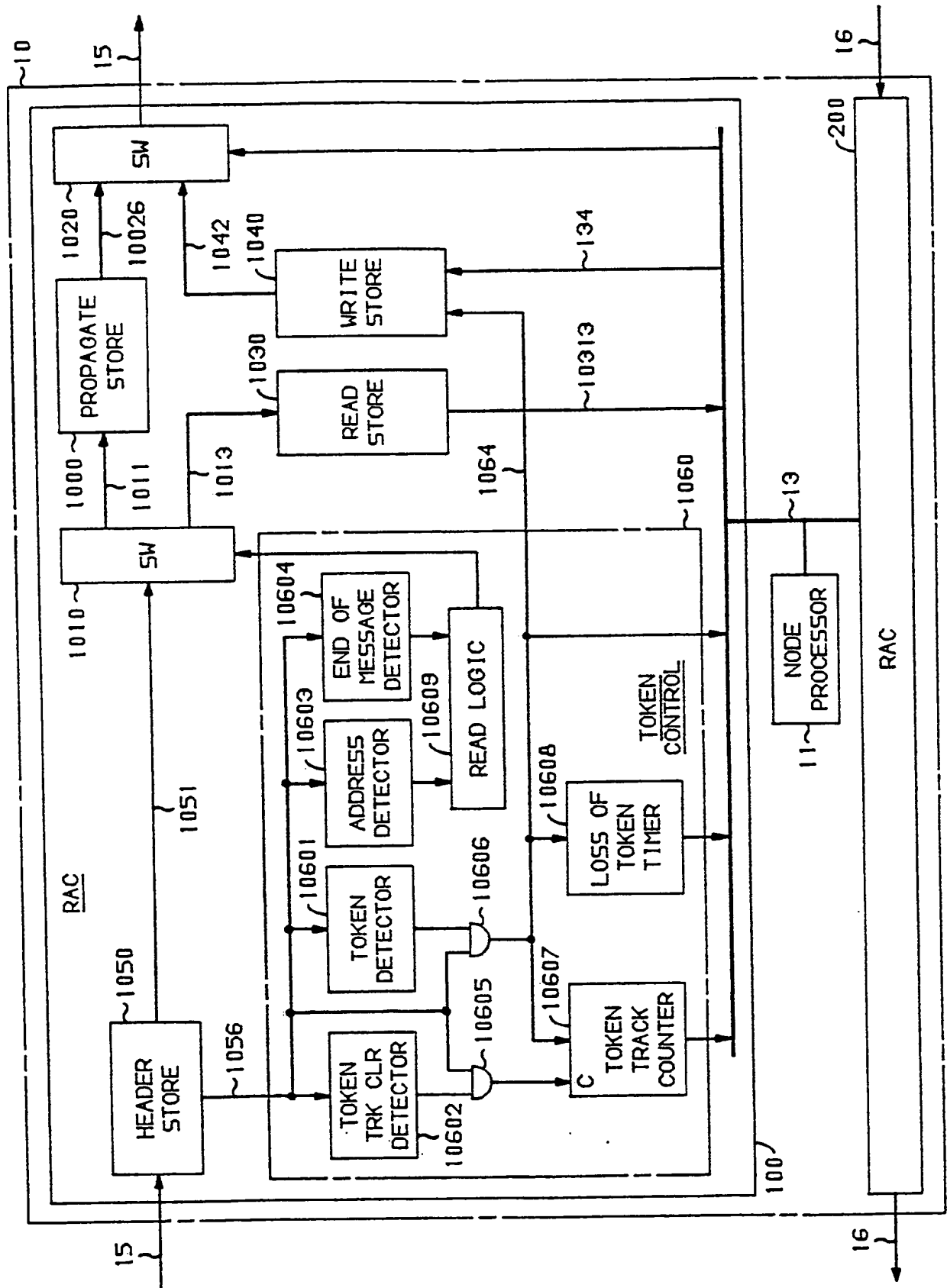
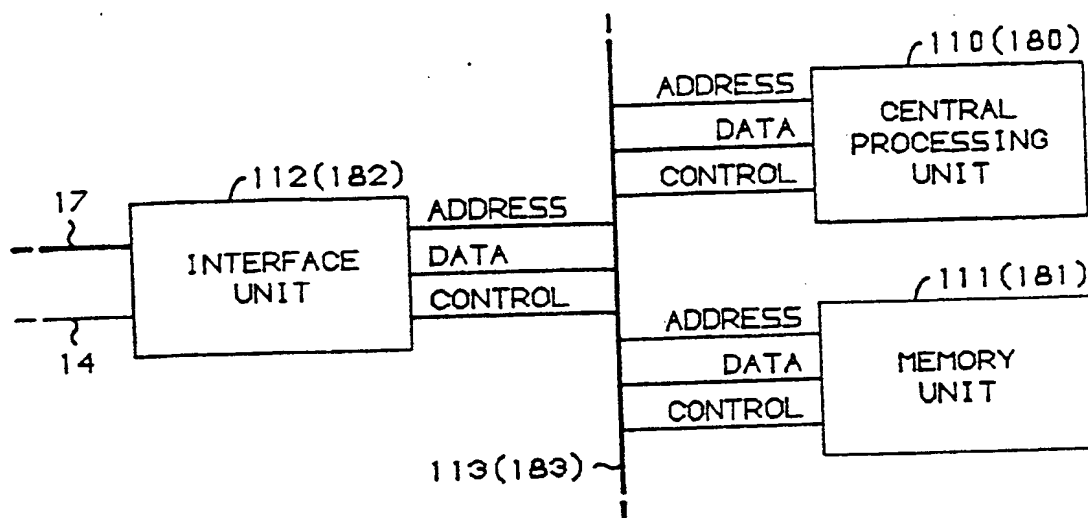


FIG. 2



PROCESSOR AND RING CONTROL  
FIG. 3

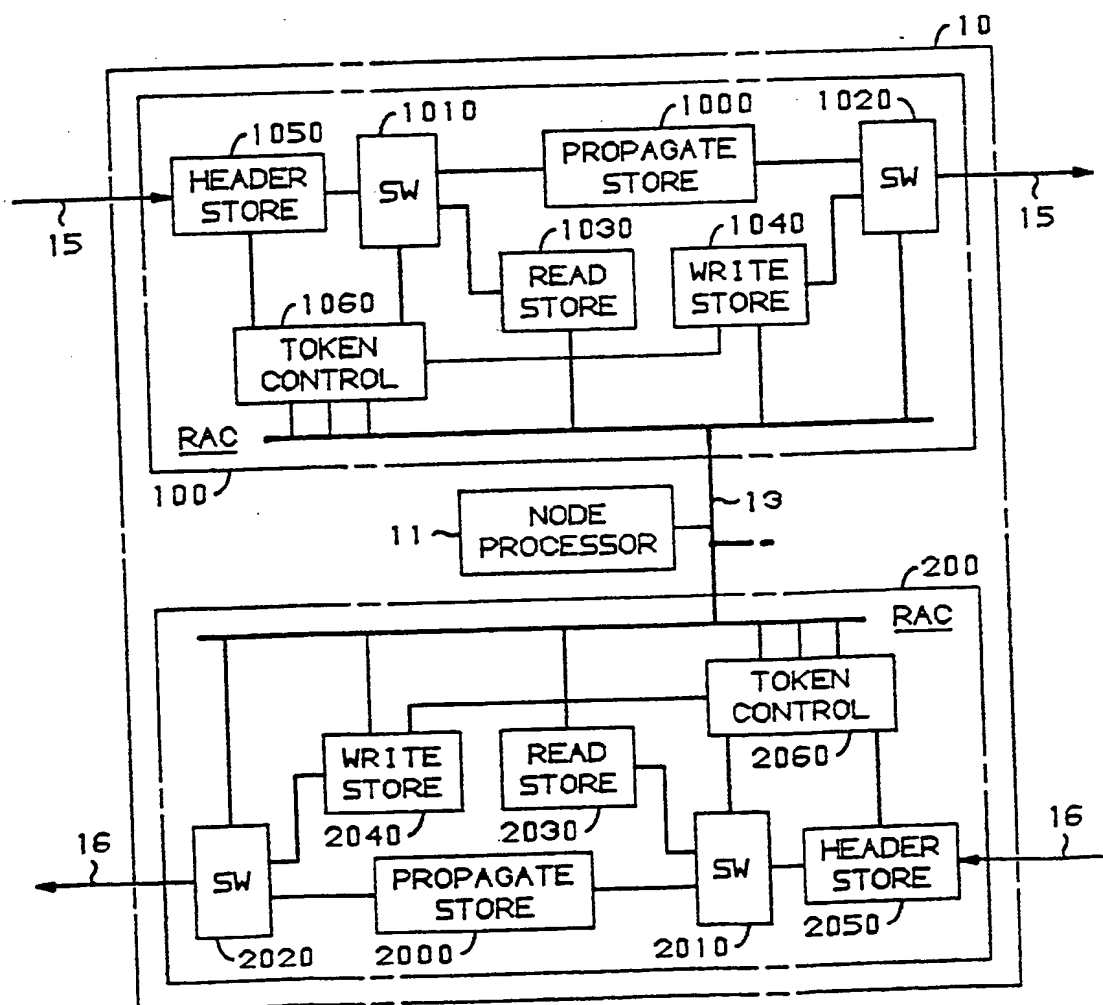


FIG. 4

FIG. 5

(111(181))

MEMORY		
ADDRESS	TOKEN TRACK COUNTER BINARY STATES	
NODE 2	0	1
NODE 3	1	0
NODE 4	0	1
NODE 5	0	1
NODE 6	0	1
NODE 7	0	1



FIG. 7

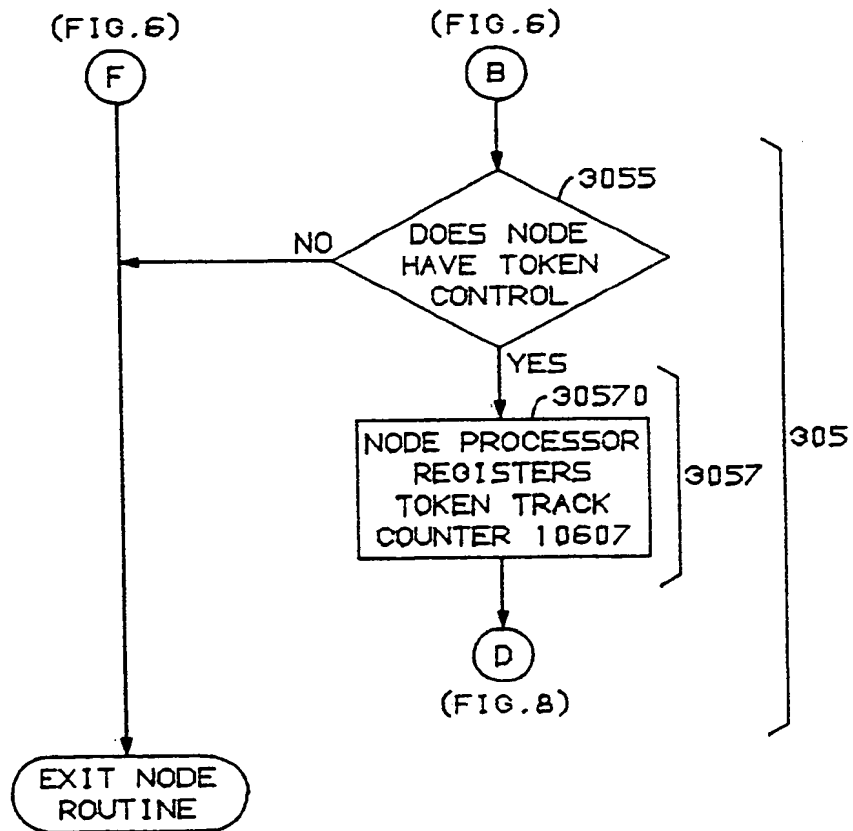




FIG. 8

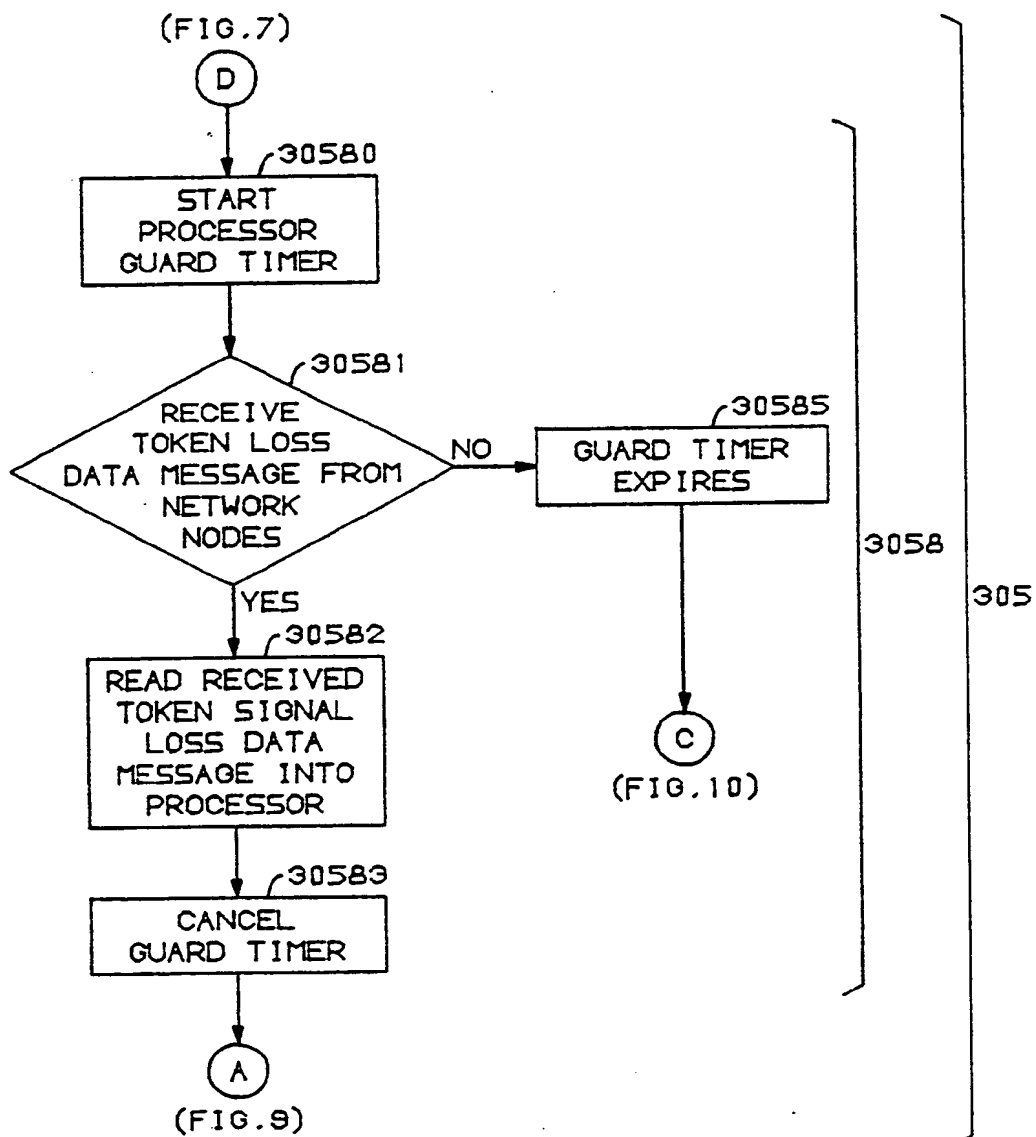


FIG. 9

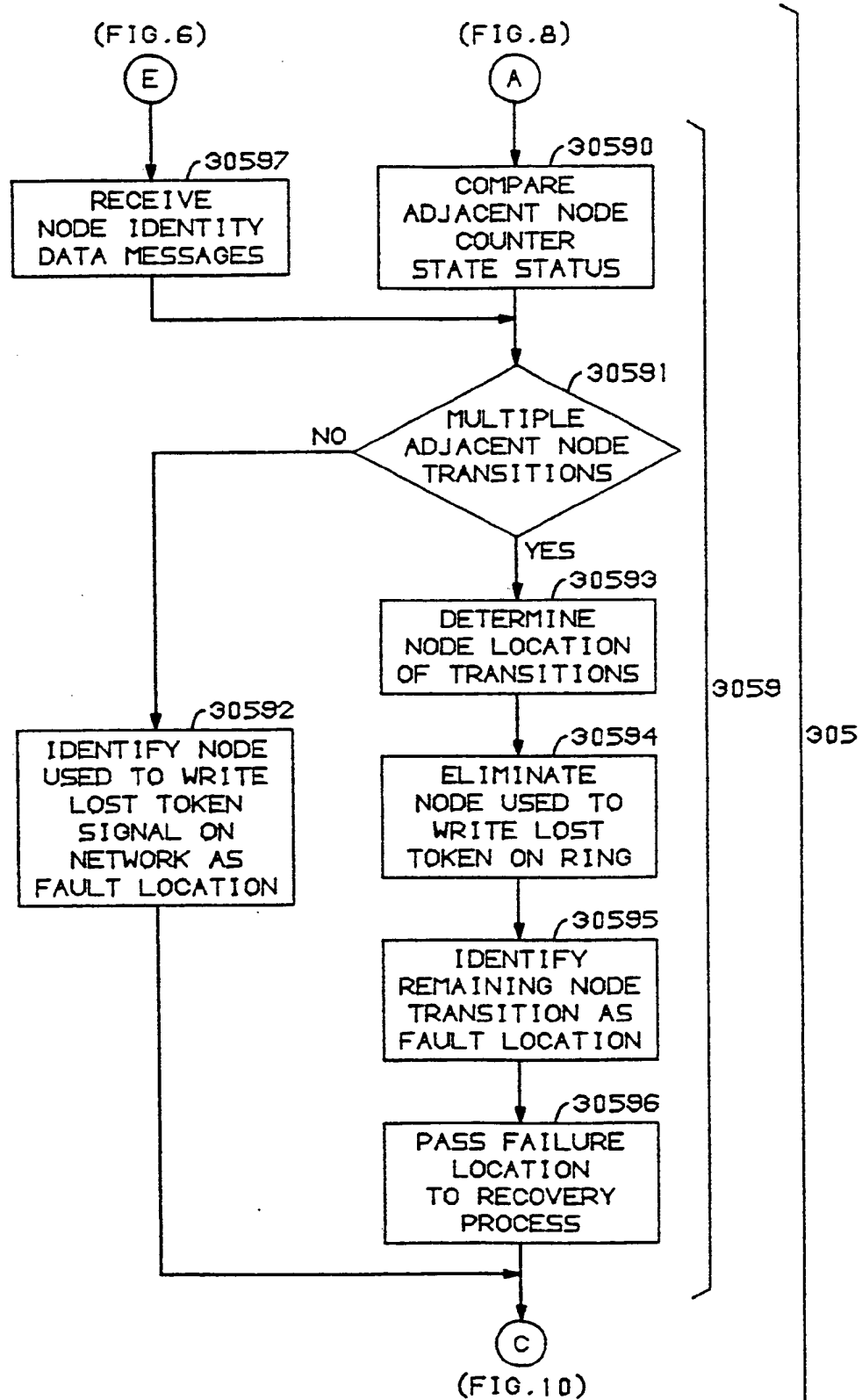
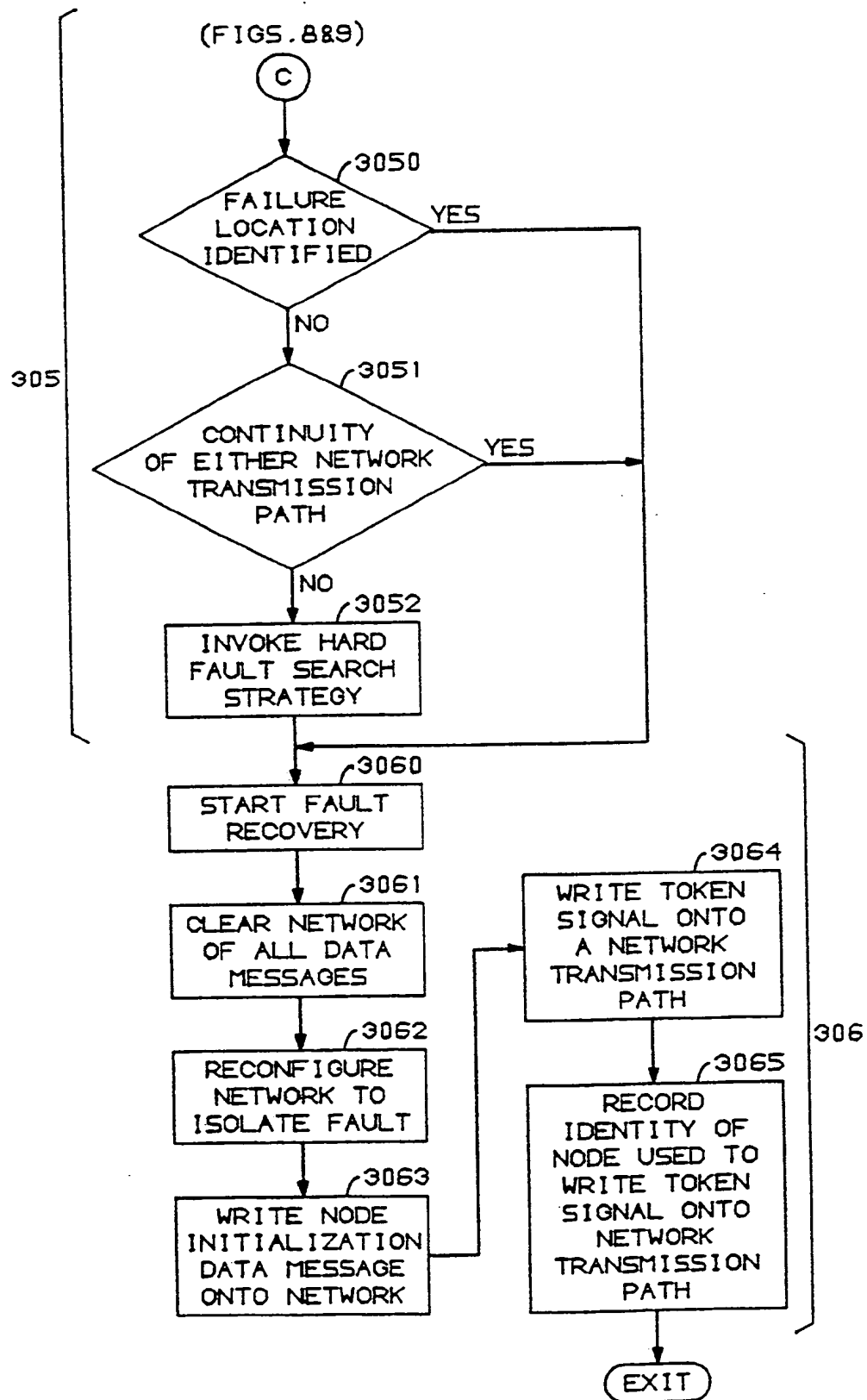


FIG. 10





European Patent  
Office

## EUROPEAN SEARCH REPORT

Application Number

EP 89 30 3681

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl. 4)
A	10TH CONFERENCE ON LOCAL COMPUTER NETWORKS, Minneapolis, Minnesota, 7th - 9th October 1985, pages 124-133, IEEE, New York, US; M.J. JOHNSON: "Reliability mechanisms of the FDDI high bandwidth token ring protocol" * Paragraphs 3.3-3.5, 4.1.3 *	1-10	H 04 L 11/16
A	IEEE INTERNATIONAL CONFERENCE ON COMMUNICATIONS '87, Seattle, Washington, 7th - 10th June 1987, pages 378-382, IEEE, New York, US; A.D. FERGESON et al.: "The AT&T interprocess message switch architecture"		
			TECHNICAL FIELDS SEARCHED (Int. Cl. 4)
			H 04 L
The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 28-07-1989	Examiner MIKKELSEN C.
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document	

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